HWG | HARRIS, WILTSHIRE & GRANNIS LLP

August 20, 2020

Ex Parte

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295; *Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz*, GN Docket No. 17-183

Dear Ms. Dortch:

On August 18, 2020, representatives from the Wireless Research Center of North Carolina and from Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Intel Corporation, NXP Semiconductors, and Qualcomm Incorporated met with Commission staff from the Office of Engineering and Technology via videoconference and telephone. A complete list of participants is attached to this letter.

We discussed the attached presentation regarding measurements of signal attenuation caused by the human body related to proposed very-low-power ("VLP") device operation in the 6 GHz band and the difference between far-field body loss and on-body link loss measurements.

Pursuant to the FCC's rules, I have filed a copy of this notice electronically in the above referenced dockets. If you require any additional information, please contact the undersigned.

Sincerely,

Paul Margie
Counsel to Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., and Google LLC

cc: meeting participants

MEETING ATTENDEES

Monisha Ghosh (CTO)

Bahman Badipour (OET)
Navid Golshahi (OET)
Michael Ha (OET)
Ira Keltz (OET)
Nicholas Oros (OET)
Aspasia Paroutsas (OET)
Barbara Pavon (OET)
Hugh Van Tuyl (OET)
Aole Wilkins El (OET)

Koichiro Takamizawa, Wireless Research Center of North Carolina
Shruthi Soora, Wireless Research Center of North Carolina

Chris Szymanski, Broadcom Inc.
Peter Ecclesine, Cisco Systems, Inc.
Larry Alder, Facebook, Inc.
Priscilla Argeris, Facebook, Inc.
Guillaume Lebrun, Facebook, Inc.
Alan Norman, Facebook, Inc.
Michael Tseytlin, Facebook, Inc.
Raymond Hayes, Google LLC
Nihar Jindal, Google LLC
Megan Stull, Google LLC
Reza Arefi, Intel Corporation
David Horne, Intel Corporation
Hassan Yaghoobi, Intel Corporation
Yi-Ling Chao, NXP Semiconductors
John Kuzin, Qualcomm Incorporated
Tevfik Yucek, Qualcomm Incorporated

Paul Caritj, Harris, Wiltshire & Grannis LLP
Joely Denkinger, Harris, Wiltshire & Grannis LLP
Paul Margie, Harris, Wiltshire & Grannis LLP

WRC Body Loss Testing and Analysis for 6 GHz

August 2020

Wireless Research Center (WRC)

- Nonprofit research center advancing global innovation with engineering and testing for wireless technologies
- WRC supports both government and commercial sectors

WRC

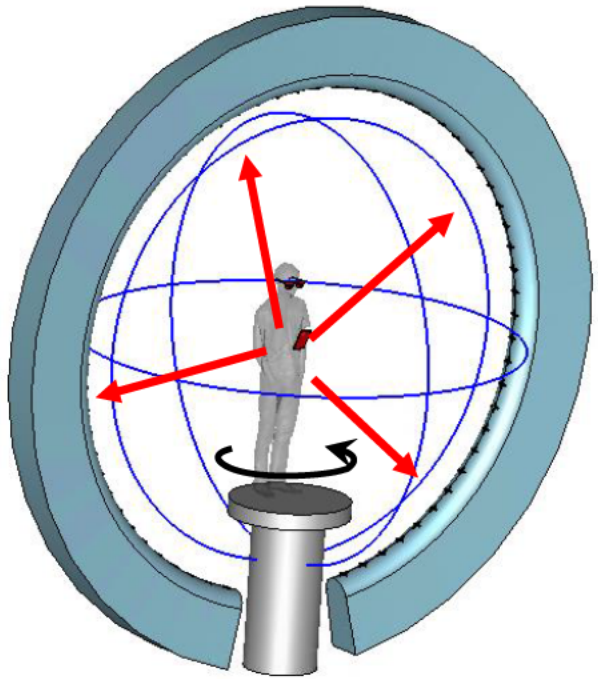
wireless research center	**R&D Engineering & Testing**
R!OT	**IoT Acceleration (convener, program facilitator, community lab)**
	DoD & Public Safety
Advanced Mobility Collective	**Advanced Mobility (air, ground, sea)**
Connected Communities	**Connected Communities (infrastructure solutions)**

Wireless Research Center Testing Accreditation

- WRC maintains ISO 17025:2017 accreditation on:
  - IEEE Std 149: Standard Test Procedures for Antennas
  - CTIA Test Plan for Wireless Devices Over the Air Performance
  - Verizon Over the Air Radiated Performance

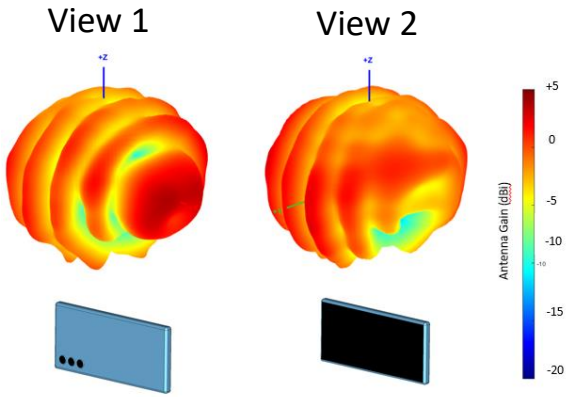
Test Summary

- Two major test objectives:
  - Develop a CDF antenna gain model of the body worn device (DUT1) & head worn AR/VR glasses (DUT2) operating at 6 GHz band on human subjects
  - Develop link loss models between the body worn device (DUT1) & AR/VR glasses (DUT2) at 6 GHz band on human subjects
- Both measurements were executed inside WRC's Satimo SG-64 Antenna Test Chamber
  - Antenna radiation patterns measured using SG-64 (Red Arrows)
  - Link losses measured using a Vector Network Analyzer (VNA) (Green Arrow)



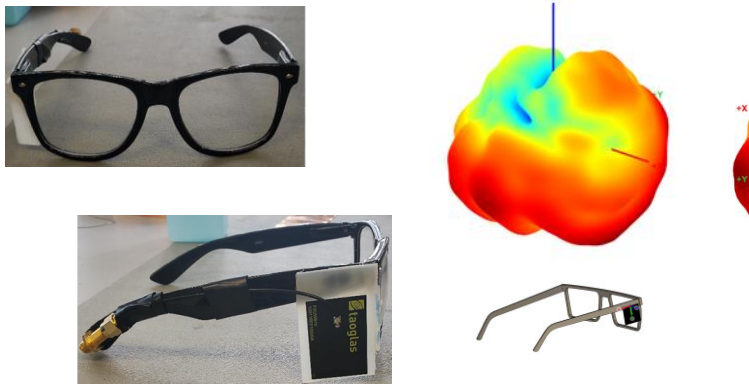
Devices Under Test

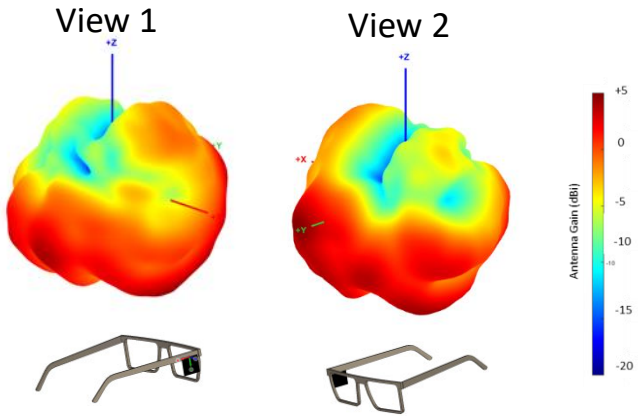
Body Worn Device (DUT1)



- Mimics the size of a mobile handset
- Pulse W3540 chip antenna on a Pulse evaluation PCB board and extended grounds (73 x 162 mm)
- Surrounded by a plastic external phone case with belt clip
- Antenna efficiency and gain are better than typical handset implementation
  - Free Space Efficiency = -1.6 dB
  - Free Space Peak Gain = 3.8 dBi

Glasses (DUT2)





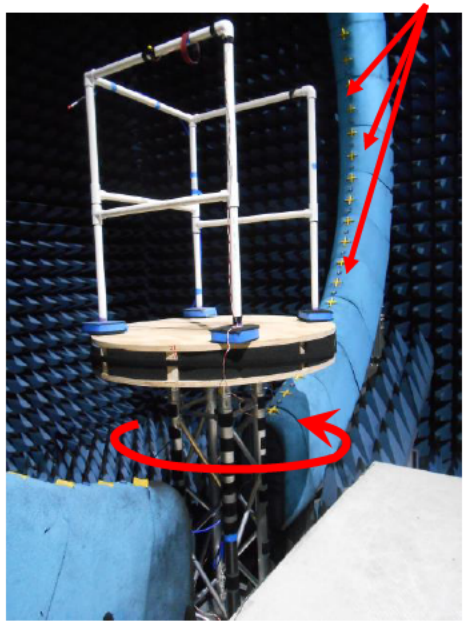
- Mimics a smart glasses product
- Taoglas FXUWB10.01.0100C flex antenna mounted on right temple arm
- Antenna oriented to produce peak toward bottom of glasses (towards feet)
- Antenna efficiency and gain are better than a typical glasses implementation
  - Free Space Efficiency = -1.0 dB
  - Free Space Peak Gain = 4.9 dBi

Antenna Gain CDF based on 3D Antenna Patterns of the Body Worn Device and Glasses on Human Subjects

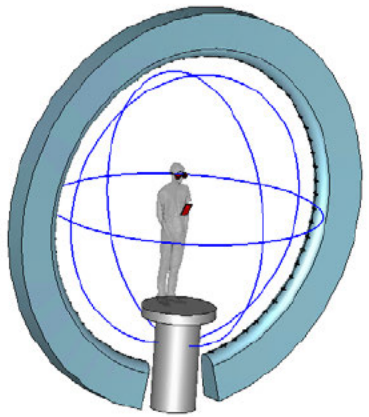
3D Antenna Radiation Pattern Measurements

- 3D antenna radiation patterns were measured using WRC's SG-64 Antenna Test Chamber

SG-64 Probes

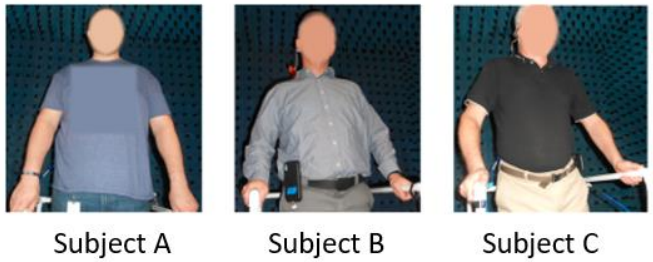


- SG-64 is a multi-probe spherical near-field chamber
  - Amplitude and phase of near-field signals in two orthogonal polarizations are measured using a set of 62 probes positioned in an arc at every 5.3 degrees
  - Probes are electronically switched during measurements
  - The turn table is rotated 180 degrees to scan full spherical near-fields of the standing test subject located on the turn table
  - The height of the turn table was adjusted to ensure the DUT was in the chamber quiet zone
  - Far-field radiation patterns are mathematically calculated from the measured near-fields using a well established near-to-far field transform technique
  - Gain of the radiation pattern is determined using the gain substitution method by measuring a reference horn antenna with NIST traceable gain values in the same chamber

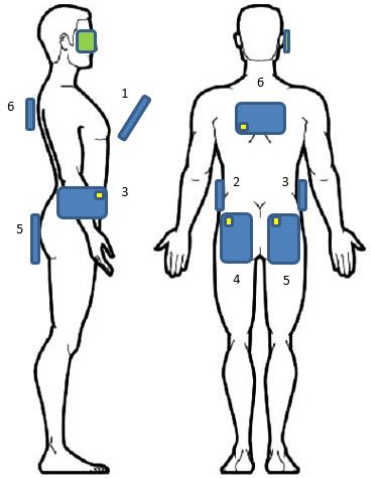


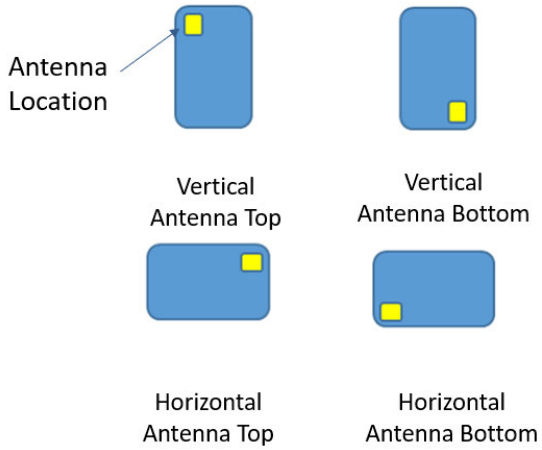
Antenna Radiation Pattern Measurement Test Conditions

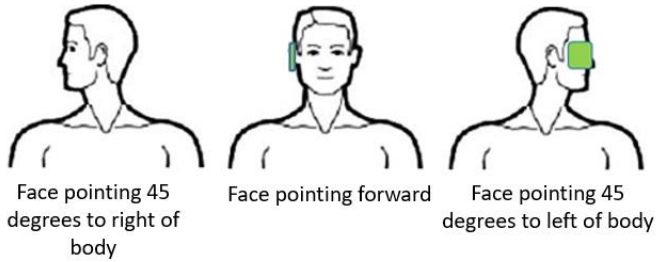
- Test Subject A Only (24 Body Worn Test cases, 3 Glasses Test Cases)
  - Six body worn device test positions
  - Four device orientations at each test position
  - Glasses tests with three head pointing directions



- All 6 Test Subjects (12 Body Worn Test Cases, 6 Glasses Test Cases)
  - 3 male, 3 female in normal, overweight and obese categories
  - Two body worn device test positions
    - Left Back Pocket – Vertical Antenna on Top
    - Back Pack – Horizontal Antenna on Top
  - Glasses tests with head pointing forward

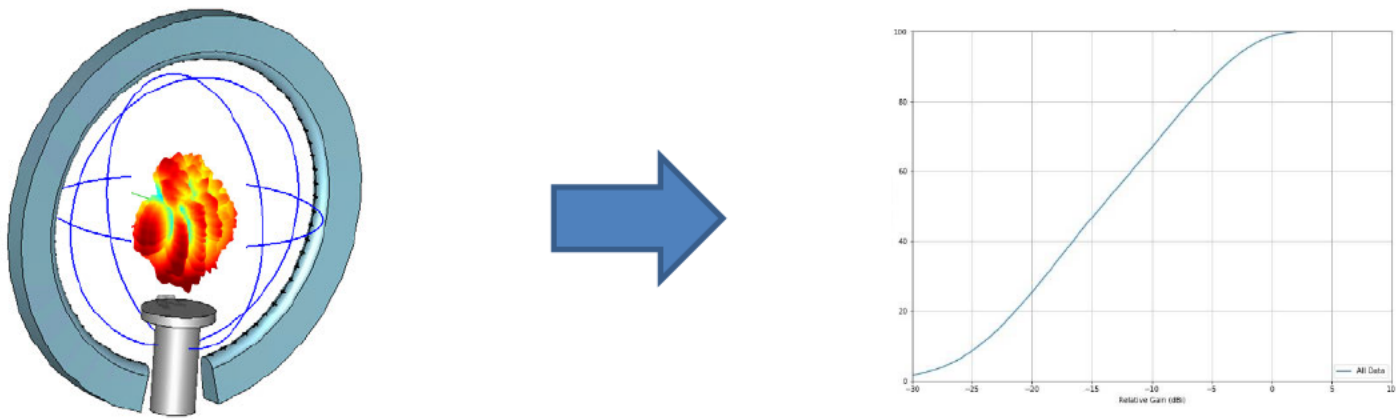






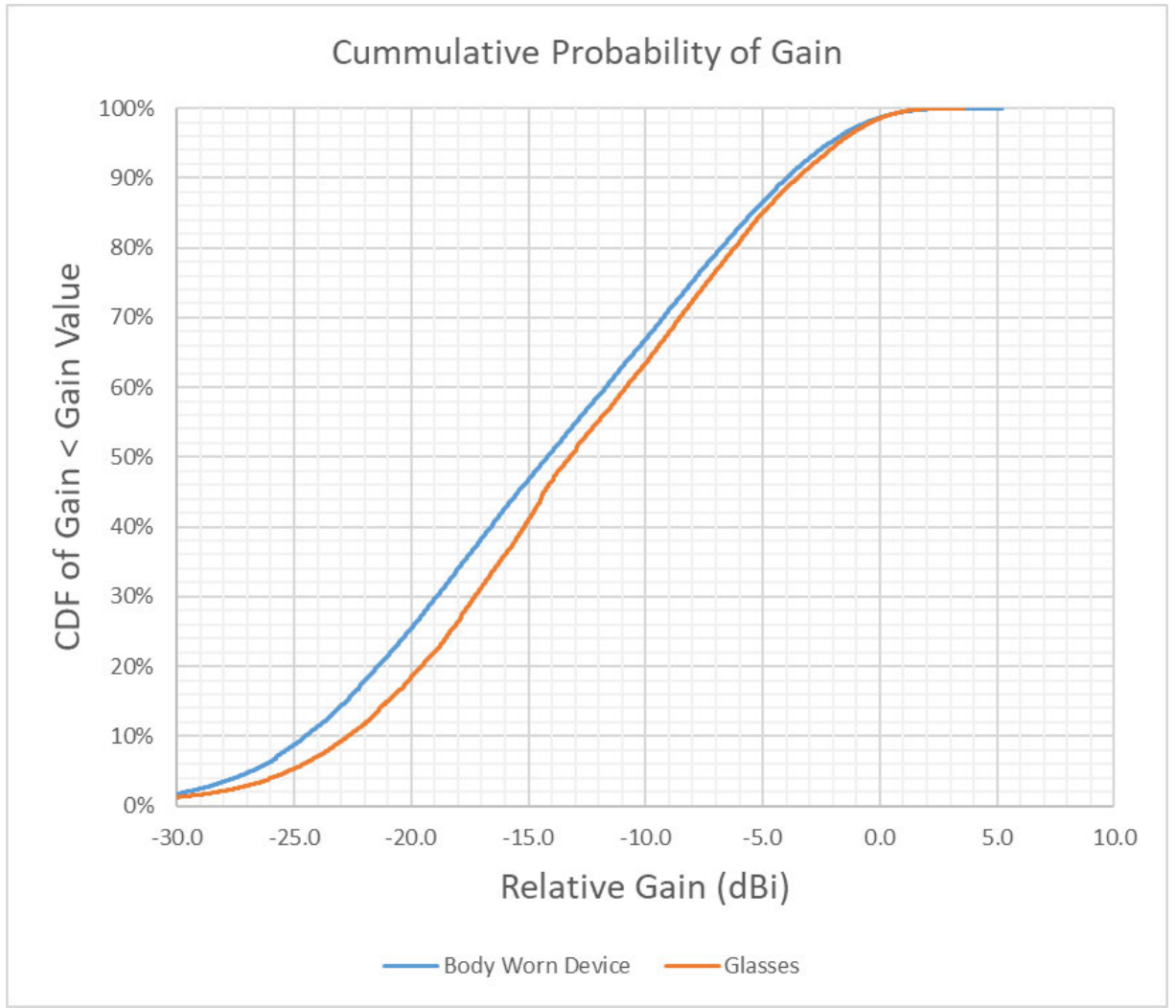
Relative Gain CDF Calculation Process

- For each test case, far-field pattern over a full sphere in two polarizations are determined
  - Azimuth angles from 0 to 360 degrees at 3 degree steps
  - Elevation angles from -90 to +90 degrees at 3 degree steps
  - 120 x 61 = 7320 independent directions over a sphere
- The total gain is polarization independent and is determined by taking the vector sum of the two polarization patterns for each direction
- The relative gain over a sphere is determined from the measured gain values by subtracting the free space peak gain of the DUT1 (3.8 dBi) and DUT2 (4.9 dBi) from the measured pattern for each subject and test position
- Since there are more points distributed near the poles of the sphere (Elevation Angle at +/- 90 degrees), cos(Elevation Angle) weights are applied to the calculation of CDF of relative gain over a sphere



CDF of Relative Gain of DUT1 and DUT2 for All Subjects, All Test Positions

- Plot shows the CDF curve for all 6 subjects, all measured positions for the Body Worn Device (DUT1) and Glasses (DUT2)
- The relative gain includes changes in the spherical antenna gain pattern when the devices are worn on the body from the free space pattern, and body loss/effects
- Body Worn Device Statistics (blue)
  - Includes 36 different test cases with 7320 points from each 3D pattern
  - Median = -14.3 dBi*
- Glasses Statistics (orange)
  - Includes 9 different test cases with 7320 points from each 3D pattern
  - Median = -13.3 dBi



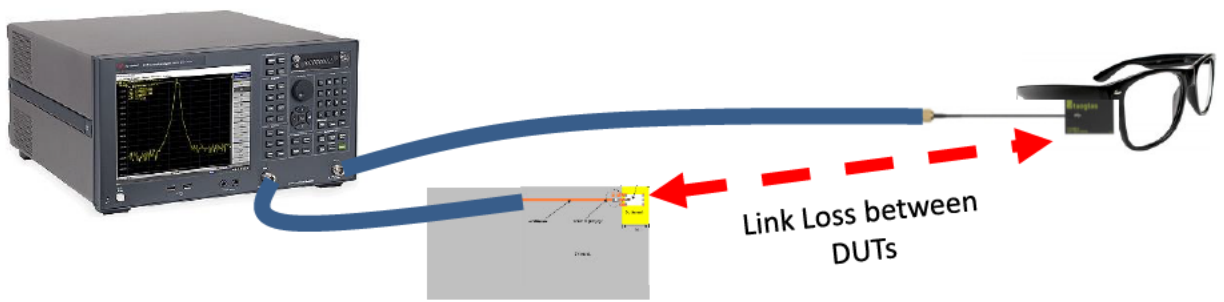
*In the report, median was incorrectly reported as mean. *See* Wireless Research Center of North Carolina, *On-Body Channel Model and Interference Estimation at 5.9 GHz to 7.1 GHz Band* at 9-10 (June 2020).

Body Worn Device to Glasses Link Loss Measurements and Model on Human Subjects

Link Loss Measurements

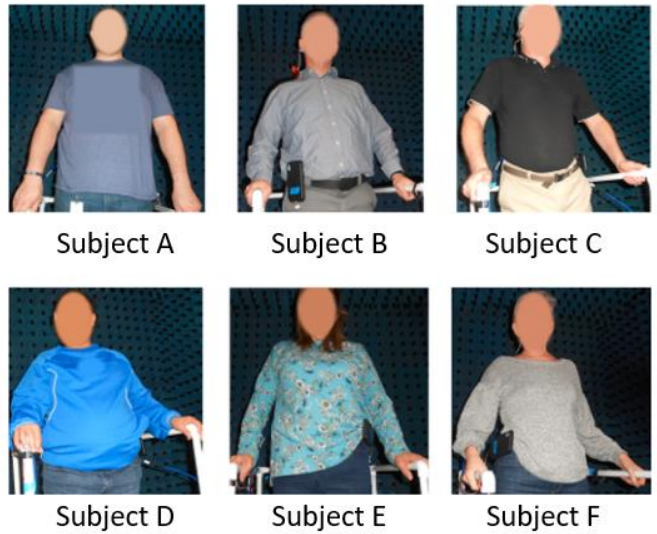
- Measured S-parameters between body worn device (DUT1) at 6 test positions and glasses (DUT2) in SG-64 antenna test chamber using a Vector Network Analyzer (VNA)
  - S21 represents Link Loss between DUT1 and DUT2
  - Swept frequency range from 5800 MHz to 7200 MHz at 1 MHz step
  - 10 frequency sweeps at each test position

- Measured Link Loss includes path loss and antenna gains of DUT1 and DUT2
  - $Link\ Loss = Gain_{DUT1} + Gain_{DUT2} + Path\ Loss$

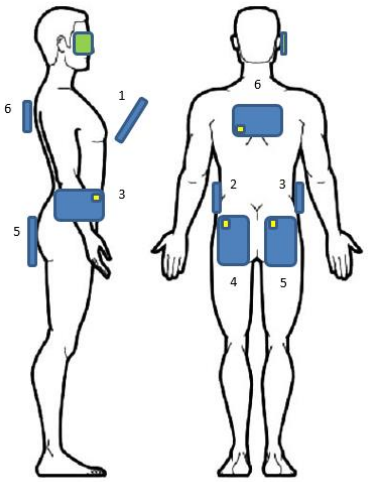


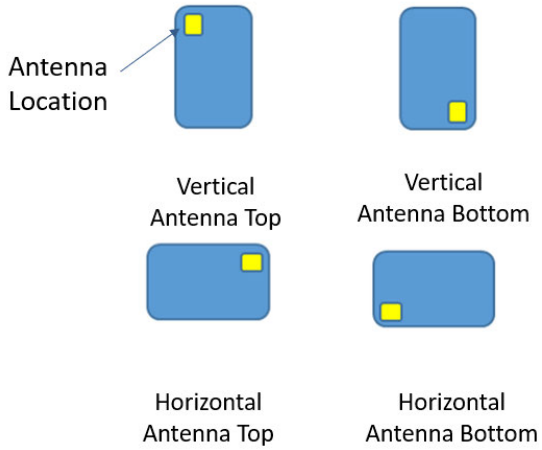
Link Loss Measurement Test Conditions

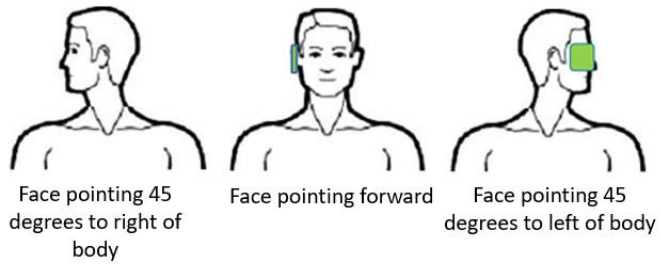
- Test Subject A Only (72 Test cases)
  - Six body worn device test positions with four device orientations
  - Three head pointing directions
  - Tests conducted with no body motion (static test)



- All 6 Test Subjects (36 Test Cases)
  - Six body worn device test positions with one device orientation
  - Test subjects allowed to make small body movements during testing including head pointing direction change (dynamic test)



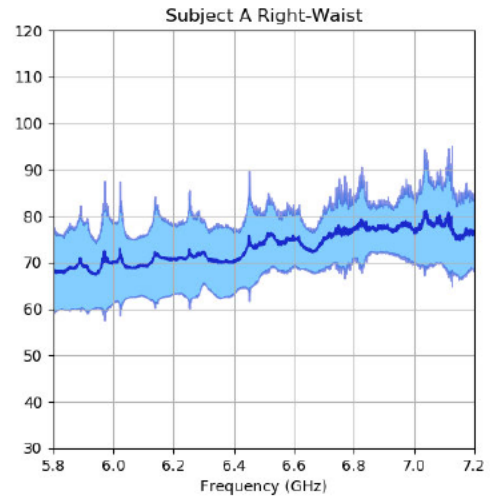


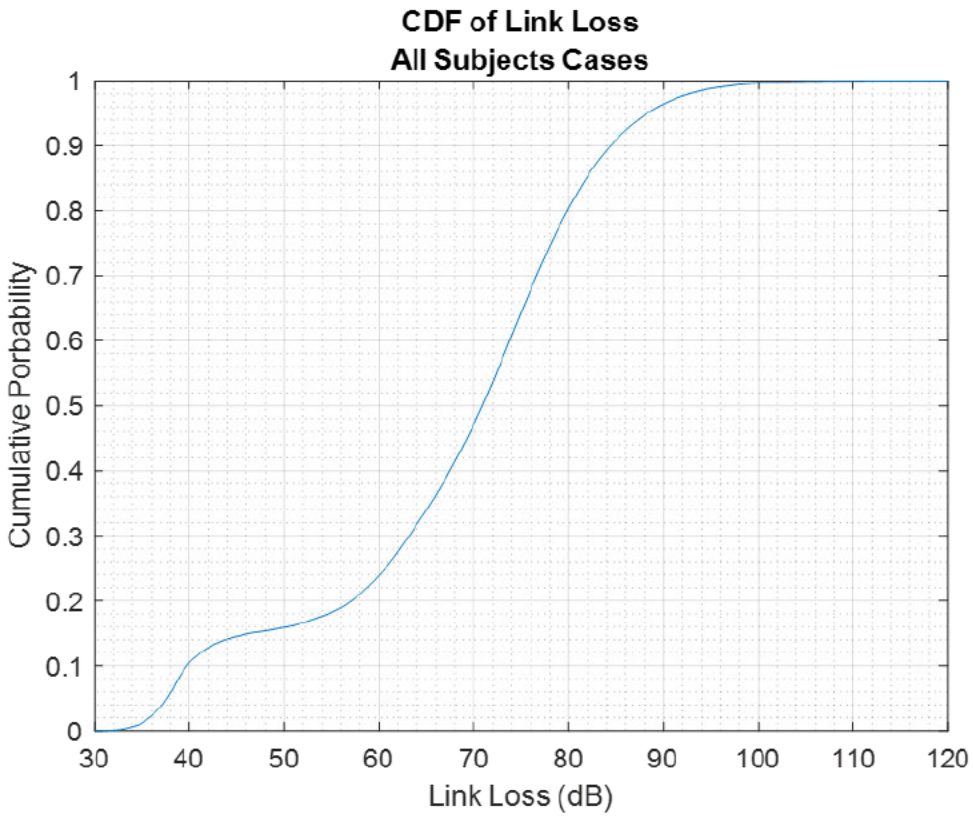


Generalized Link Loss Model for Body Worn Device to Glasses in 6 GHz Band

- Link loss was measured at each position for 10 frequency sweeps (5800-7200 MHz at 1 MHz steps) resulting in 14,010 total points
- Link loss includes separation distance, antenna pattern mismatch, body effects/loss, polarization mismatch loss
- Link Loss CDF includes all 108 test cases
  - ~1.5 million total points
  - 6 test subjects in static and dynamic positions at 6 GHz

Example of Measured Link Loss at 1 position





Summary

- Developed a CDF antenna gain model for the 6 GHz band based on the radiation pattern of body worn devices in multiple locations on 6 human subjects

- Calculated 6 GHz statistical link loss models between a body worn device and AR/VR glasses based on measurements on 6 human subjects and multiple device locations and orientations